THERMAL CONTROL VALVE DEVELOPMENT FOR SYSTEM SURVIVAL DURING LOW TEMPERATURE SINK CONDITIONS. Michael C. Ellis[1], Ion Nicolaescu[1], Max Demydovych[1], William G. Anderson[1], [1]Advanced Cooling Technologies, Inc., 1046 New Holland Avenue, Lancster, PA 17601, mike.ellis@1-act.com.

Introduction: The lunar night poses a significant challenge in the thermal management of landers and rovers operating on the lunar surface. This is especially true for long duration missions, in which the on-board electronics of these vehicles must be maintained within their survival temperature range to ensure mission success. As the radiator is sized to reject heat during the lunar day, excessive heat rejection during the low temperature lunar night is unavoidable. One solution to this challenge is a component that could provide a thermal disconnect between the electronics and radiator when the sink temperature drops below a specific value and then re-establishes heat rejection once temperatures are again favorable.

As part of a NASA Small Business Innovative Research (SBIR) Sequential Phase II project, Advanced Cooling Technologies, Inc. (ACT) is developing a Thermal Control Valve (TCV) that provides a means to passively stop coolant flow to a radiator based on a user-defined set point. This valve is placed after the pumping mechanism of the coolant loop, such as the evaporator of a Loop Heat Pipe (LHP). ACT has developed two styles of valve with each style named after their reaction to the set point temperature.

A Closed-When-Cold (CWC) valve stops the flow of coolant to the radiator when the coolant temperature drops below a specific set point. As the coolant temperature increases above this set point, the valve allows the flow of coolant to the radiator to resume. An Open-When-Cold (OWC) valve does not directly control coolant flow to the radiator but instead opens a bypass between the inlet and outlet to the coolant pump. Since the pressure drop through the radiator is much higher than the bypass, opening the bypass effectively stops coolant flow to the radiator. These valve types can be used separately or together, depending on the needs of the application.

The valves actuate as a result of the force balance between two opposing pressures: the saturation pressure of the coolant and the set point pressure. As the set point pressure is adjusted, a different saturation pressure is required to open or close the valve. This effectively changes the set point temperature for valve actuation. This effect can be seen in Figure 1. During this test of an OWC valve, the radiator temperature was maintained at a low temperature so that valve opened and a minimum coolant temperature was reached. The set point pressure was then increased, which resulted in an increase in the minimum coolant temperature.

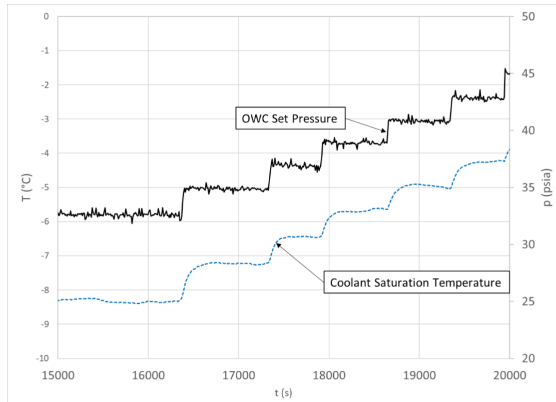

Figure 1. Test data showing the effect of the set point pressure on the minimum saturation temperature of a LHP.

In a test of the CWC valve, the radiator temperature was varied across a 70 K range. The valve was set to actuate at approximately 10 °C. There is an initial coolant temperature spike during LHP start up as the vapor channels are cleared of liquid [1]. After that, the coolant temperature drops until the set point temperature is reached and the valve closes. As the radiator temperature increases, the valve opens and the coolant temperature increases as the LHP operates again.

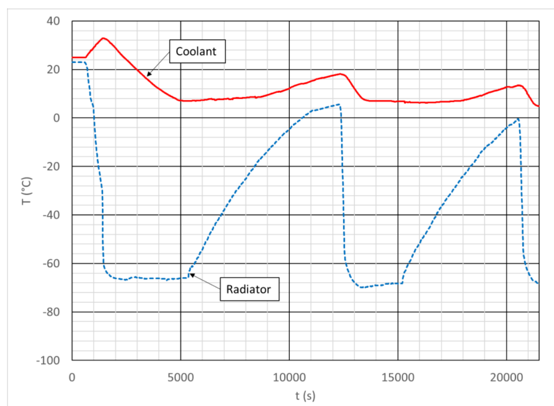

Figure 2. Temperature data obtained during testing of a LHP with a CWC valve and varying sink temperature.

ACT recently fabricated the second prototypes. The design of these prototypes focused on reducing size, mass, and fabrication time. Each new design will undergo thermal vacuum testing, thermal cycling, and shock and vibration testing.

References: [1] Ku, J. (2016). ICES (2016-24).

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